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DESIGN, SIMULATION AND EVALUATION OF ADAPTIVE CRUISE CONTROL FOR VEHICLES

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Abstract

In this project, cruise systems technologies were mentioned. The current application of cruise systems is explained. Modeling was done according to the longitudinal dynamics of the linear and non-linear vehicle and the adaptive cruise system was modeled. The vehicle model created was taken as an example of the automatic transmission vehicle model published in Matworks. The gas-brake system is designed according to the driver's character. The vehicle was modeled on MATLAB/Simulink and then the controller was designed with the Adaptive Cruise System ACC model. In order to obtain the transfer function of the system, the transfer function was obtained by the System Identification method with MATLAB/Simulink Tool. The working logic of the genetic algorithm is explained and then applied. While designing the controller of the system, different sources were examined and the PD controller design was made. Apart from the root locus, which is a manually calculated method, PID tune was made with Genetic Algorithm optimization, which is a machine learning method, in order for the system to work with a different optimal controller. Finally, the comparison of the controllers was made and the project was terminated.

I. Introduction

The aim of this project is to design an Adaptive Cruise system for vehicles in accordance with standards. While making this design, controllers were designed for the nonlinear vehicle model. While designing these controllers, PD designed with the root locus method which is a manual calculation, and Genetic Algorithm optimization which is a Machine Learning method. Afterwards, the performances of these controllers were compared. At the same time, MATLAB/System Identification Tool was used to estimate the transfer function according to the response of the system whose parameters are unknown. SISO Tool/Control System Toolbox was used to strengthen the root locus execution.

II. ACC System Design for Nonlinear Vehicles

In this section, the controller design for the nonlinear vehicle model is made. Firstly, a model with automatic transmission vehicle model and driver characteristics was preferred [1]. Then, as seen in Figure 1, a model containing an automatic transmission vehicle model and driver characteristics was preferred [1]. The transfer function of the vehicle was obtained using the MATLAB/System Identification method. Obtained transfer function, a PD controller was designed with the root locus method and PID controller values were tuned with GA on the ACC model .

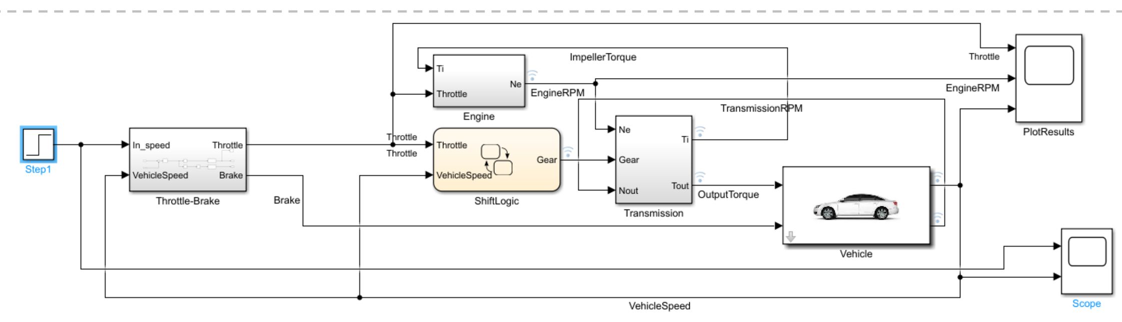

Figure 1. Simulink model of the Auto Transmission vehicle and include driver characteristic for control the throttle [1].

A. Constant Time Headway Method

This method describes the safe headway time method for Adaptive Cruise Control design

$$d_{(r,i)}\,(t) = s_i + t_{(ts,i)} v_i \qquad (1)$$

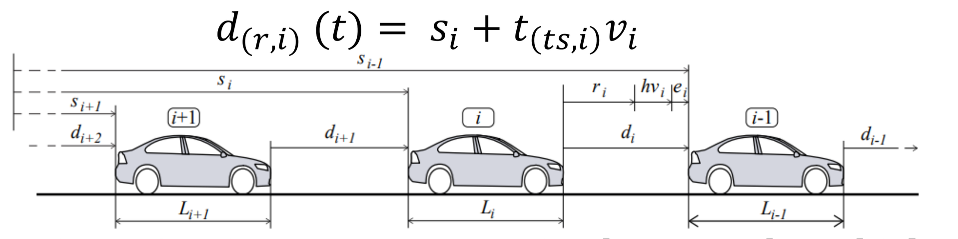

Figure 2. Distance representation between the vehicles [2].

B. Adaptive Cruise Control Design with MATLAB/Simulink

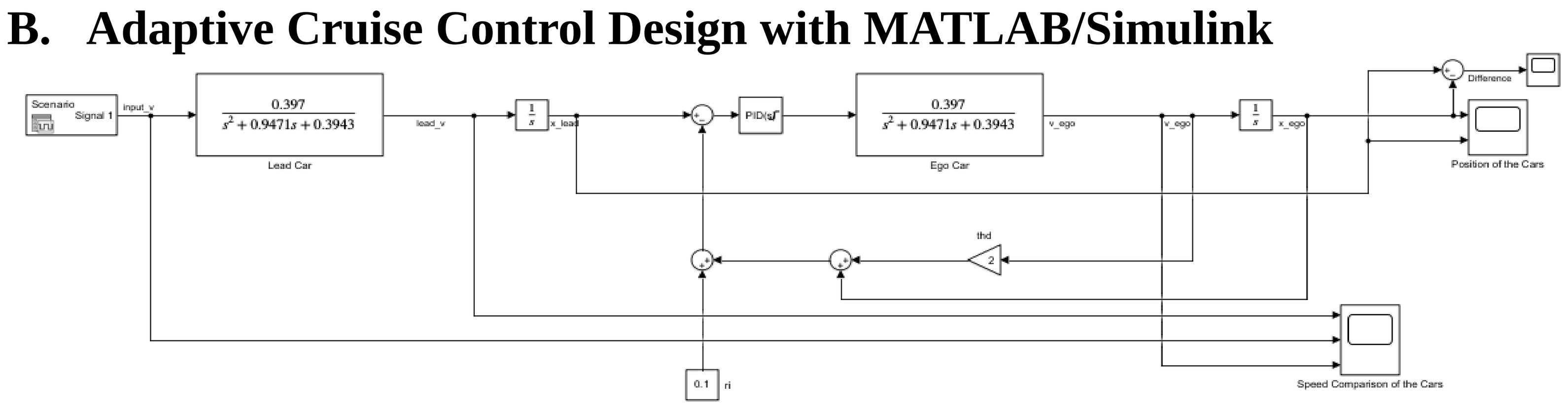

Figure 3. ACC vehicle block diagram via MATLAB/Simulink.

$$G(s) = \frac{0.397}{s^2+0.9471s+0.3943} \qquad (2)$$

C. PD Controller Design with Root Locus Method

When designing a PD controller, the design criterion was taken as a damping ratio value of 0.707 and a natural frequency value of 3.82 rad/s. According to these values, the desired closed loop poles locations were determined. Calculations were made using the angle condition and magnitude condition equations in the root locus properties. Angle calculations were made based on Figure 4. and the PD controller transfer function was obtained using condition equations. Then, it is tested in Figure 5. whether the designed PD controller meets the desired design values through the root locus of the closed loop transfer function [3].

$$\angle G(s)G_I(s)H(s) = \pm 180°(2k+1) \qquad (k = 0,1,2,) \qquad (3)$$

$$|G(s)G_I(s)H(s)| = 1 \qquad (4)$$

$$G_{PD} = 6.23(s+2.91) \qquad (5)$$

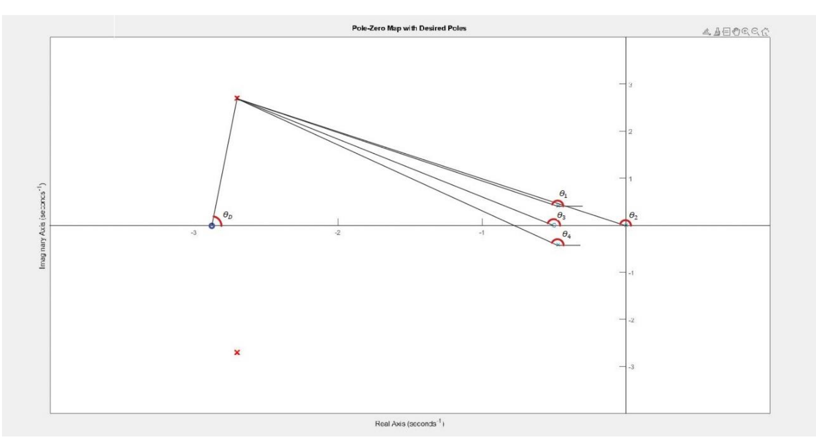

Figure 4. Angle Measurements Diagram

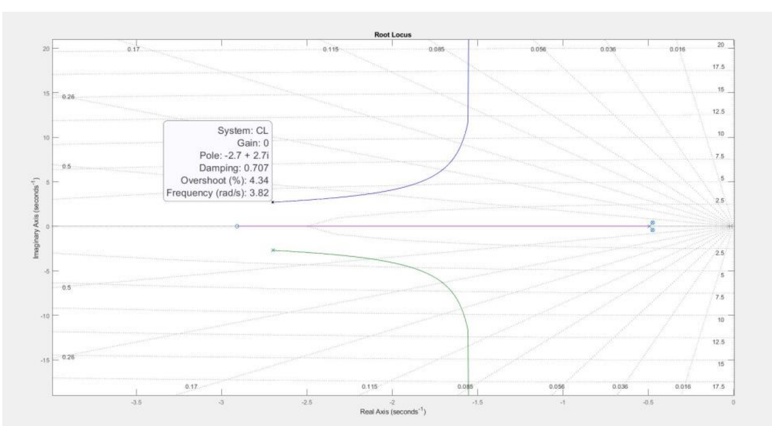

Figure 5. Root Locus of Closed Loop Compensated System

D. PID Tune with Genetic Algorithm

In this section, PID is tuned with genetic algorithm. It was made in Algorithm 1. using the Global Optimization Tool in MATLAB [4].

$$J = \Delta t \sum_{k=0}^{N} \left(Q.\left(1-y(k)\right)^2 + R.u(k)^2\right) \qquad (6)$$

Algorithm 1. Genetic Algorithm Function via MATLAB [5]

```
dt=0.001; %sampling time

PopSize=25; %population size

MaxGenerations=10; %maximum generation

s = tf('s');

G= 0.397/(s*(s^2+0.9471*s+0.3943)) %nonlinear transfer function of vehicle

options = optimoptions(@ga, 'PopulationSize', PopSize, 'MaxGenerations',… MaxGenerations); %GA function option

[x,fval] = ga(@(K)pidtest(G,dt,K),3,-eye(3),zeros(3,1))%GA function to estimate PID paramters
```

Table 1. Tuned PID values and cost (J) values according to different scenarios.

Scenario	Q	R	J	Kp	Ki	Kd
1	1	0.001	1.3321	6.9752	0	0.1199
2	1	0.01	1.6782	2.9065	0	0.0279
3	1	1	3.2679	0.5531	0.0046	0.0013
4	10	0.001	11.4173	16.1603	1.5273	0.388
5	100	0.001	105.2391	36.6277	11.5526	0.9325

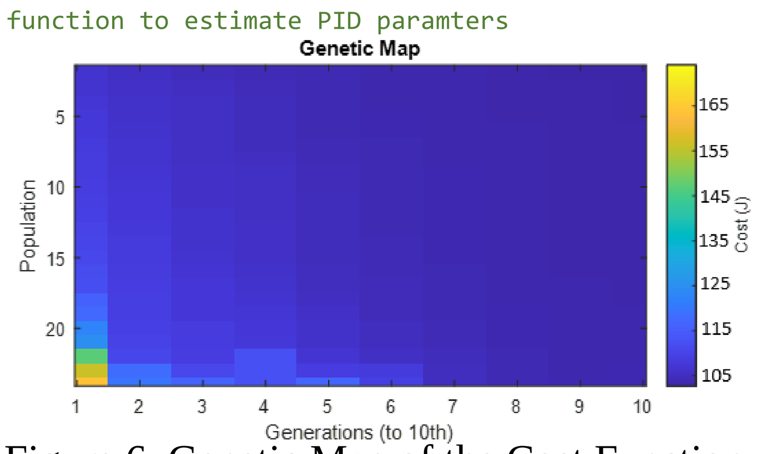

Figure 6. Genetic Map of the Cost Function

III. MATLAB/Simulink Results and Comparison of PD and GA Controllers

In this section, comparisons of designs for ACC controllers are made. Here, the desired result is expected to be close to each other. The PD controller was designed with the root locus and the PID design was made with GA. Figure 7. and Figure 9. velocity graphs are given, and the distance differences between the Lead vehicle and the Ego vehicle are given in Figure 8 and Figure 10. Comparing the methods in Figure 11 and Figure 12, the results reveal that the GA tuned system works almost without errors. This is an indication that the system works more securely.

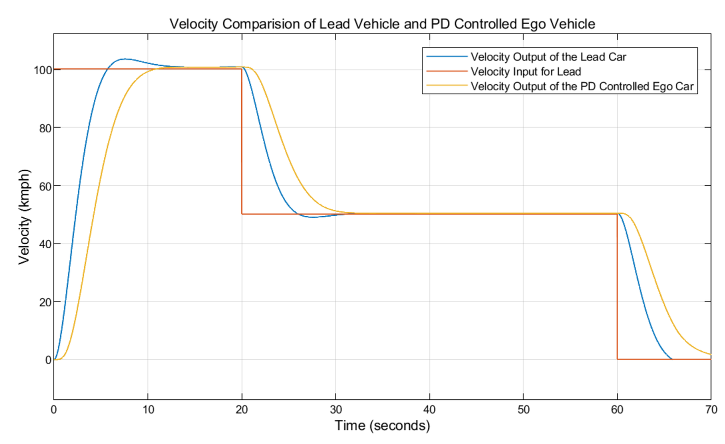

Figure 7. Velocity comparison of vehicles for PD Controller.

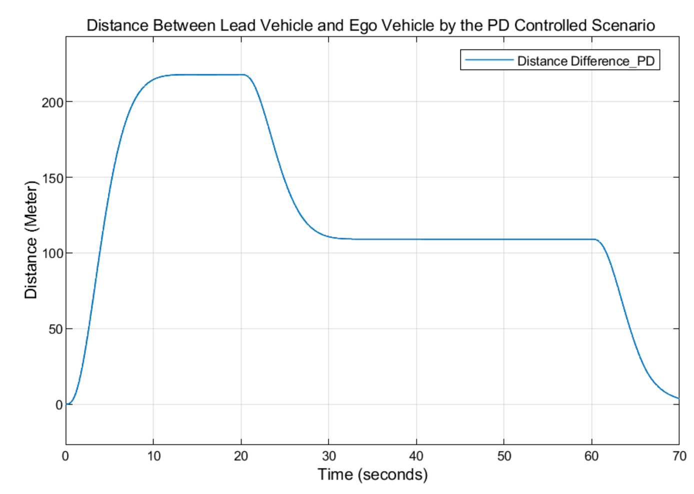

Figure 8. Distance difference between vehicles for PD Controller.

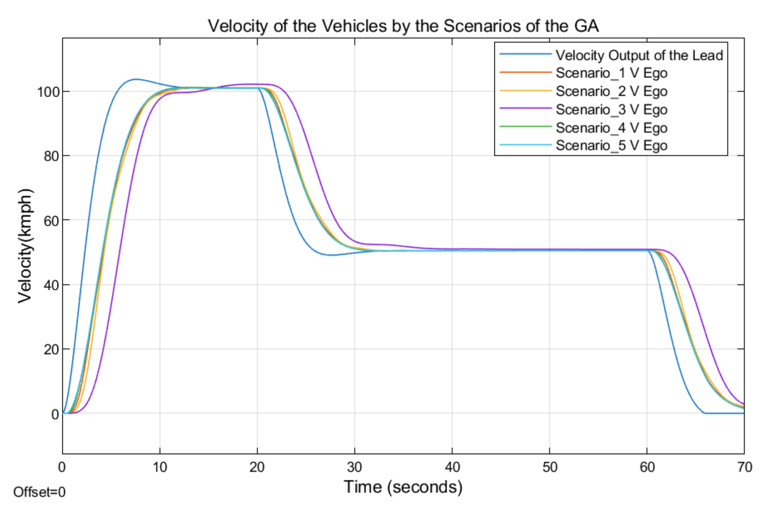

Figure 9. Velocity comparison of the vehicles by the GA scenarios.

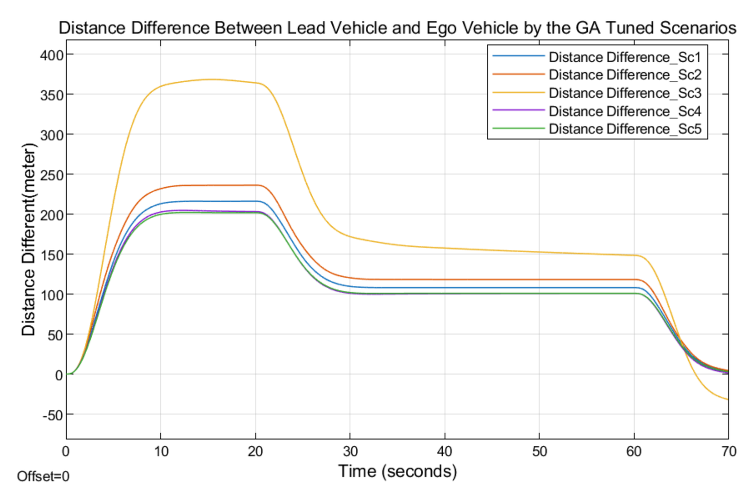

Figure 10. Distance difference between vehicles for GA scenarios.

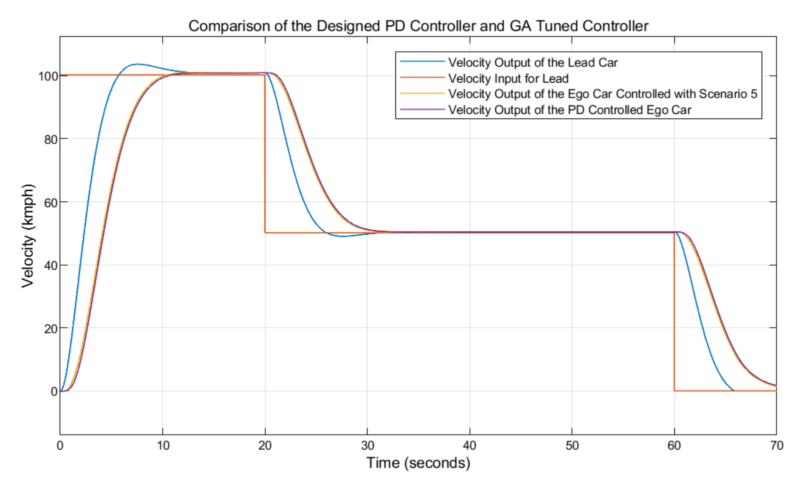

Figure 11. Velocity comparison between PD Controlled and GA Tuned Vehicles.

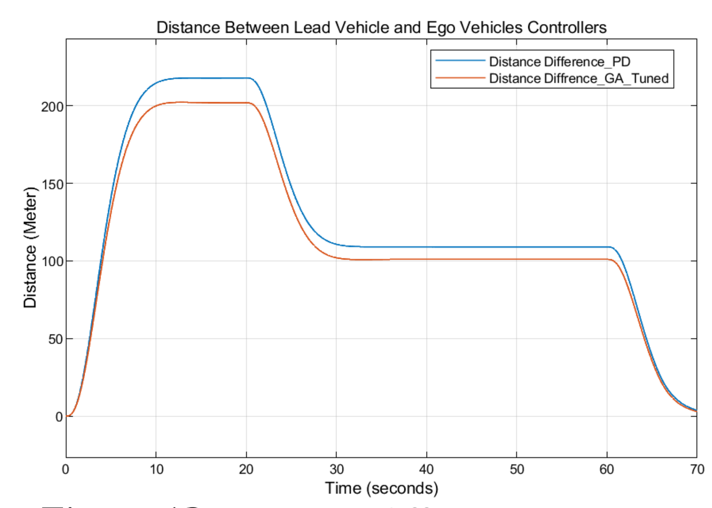

Figure 12. Distance difference comparison for PD Controlled and GA Tuned Vehicles.

Conclusion

As a result, different controller designs were made and two different methods were compared in this project. Using methods that can facilitate the development of Adaptive Cruise Systems will enable the design of better controllers in the future. Cooperative Adaptive Cruise Systems can be designed for the continuation of the project.

References

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